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CONTINUOUS SPARK IGNITION FOR RAPID RELIGHT AFTER FLAMEOUT OF GAS TURBINE ENGINES,

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John J. Rose
Propulsion Laboratory

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WADC Technical Note 59-64
March 1959

Directorate of Laboratories
Propulsion Laboratory
~~Project 912A~~

CONTINUOUS SPARK IGNITION FOR RAPID RELIGHT AFTER FLAMEOUT OF GAS TURBINE ENGINES

I. PURPOSE

1. To present information regarding results attained in efforts to establish rapid relight of gas turbine engines after flameout with continuous operation of the spark ignition system.

II. FACTUAL DATA

2. The in-flight flameout of gas turbine engines, in many instances, is the result of transient reductions in engine air flow caused by many possible conditions such as particular aircraft maneuvers, contamination of intake airflow by exhaust products of self-propelled ordnance launched from aircraft, and severe ice ingestion by the engine. If the aircraft loses altitude or flight speed due to the engine flameout, or must be piloted to lower altitude in order to relight the engine, the mission of that particular aircraft is either compromised or completely aborted.

3. The first major effort on rapid relight of gas turbine engines appears to have been accomplished by the British. In early 1956, Proteous Engines of the Bristol Britannia Commercial Aircraft experienced flameout while flying through heavy precipitation of small ice crystals at very low air temperature. The British were successful in obtaining rapid relights under these icing conditions by inserting into the combustion chamber of the Proteous engine, a platinum glow plug. Apparently the platinum rod is heated to incandescence during normal engine operation, and this heat is retained sufficiently after flameout to relight the engine. The catalytic effects of platinum upon mixtures of hydrocarbon fuels and air probably aid the relight process also. British references are listed in Appendix A.

4. The Propulsion Laboratory, Wright Air Development Center, approached the rapid relight problem quite differently than the British. In late 1957, the continuous use of spark ignition, or intermittent use of spark ignition during critical periods of flight was proposed as the most straightforward method for rapid relight of gas turbine engines. The Propulsion Laboratory itself was unable to perform rapid relight testing due to limited engine test facilities. Arnold Engineering Development Center (AEDC) undertook rapid relight tests on a YJ79-GE-3A engine at the request of the Propulsion Laboratory. Tests were conducted between 19 December 1957 and 28 April 1958 comparing the engine's spark ignition system and a platinum glow plug for rapid relight. At the conditions tested, the continuous spark ignition system was a more effective and reliable method of producing engine re-ignition following compressor stall-induced flameout than the glow plug system. AEDC reference is listed in Appendix A.

5. From the conclusions as reported by AEDC and other ground test facilities, it became increasingly obvious that the biggest problem is resolving rapid relight after flameout was to get actual simulation of conditions as experienced in-flight, i.e. short time air reduction transients through the engine. Therefore, at the request of the Propulsion Laboratory and the Weapon System Project Office, ARDC, the Directorate of Flight and All-Weather Testing, WADC, over the period from June through October 1958 performed flight tests with continuous spark ignition on F101 aircraft under icing conditions. The F101A and F101B aircraft were both tested in order to check rapid relight capabilities with the two different ignition systems. F101A aircraft have an ignition system with approximately four (4) joules stored energy and 12 sparks per second firing rate, while the F101B has an ignition system with approximately 20 joules stored energy and four (4) sparks per second firing rate. The aircraft were flown behind the KB29 tanker plane in such a position that water from the tanker boom sprayed onto the left inlet. After accumulating 1" to 1 1/2" of ice on the engine inlet lip, the aircraft were removed from the icing spray and flown to warmer altitudes to dislodge the inlet ice for ingestion by the engine. Results of the tests showed that sustained engine operation could be maintained with the spark ignition system turned on during ice ingestion. The tests also showed that a flameout was possible, during ice ingestions with the spark ignition system turned off. Flight test reports are listed in Appendix A.

6. Prior to initiation of the continuous ignition flight test by Directorate of Flight and All-Weather Test, the Propulsion Laboratory performed endurance testing on several spark ignition systems to determine the suitability of present intermittent duty systems for continuous duty operation. The present duty cycle requirement for spark ignition systems is two minutes on, three minutes off, two minutes on, and twenty-three (23) minutes off as called out in Specification MIL-E-5007A. The results of tests conducted by an engine manufacturer, an ignition system manufacturer, and the Propulsion Laboratory show that present spark ignition systems are adequate for duty cycles considerably in excess of the requirements of MIL-E-5007A, with time of operation to failure dependent upon the environmental temperature of the system.

7. Since present spark ignition systems operating on direct current are not capable of continuous operation over long periods of time, the Propulsion Laboratory designed a continuous duty system using components presently available which does not have the limitations of the ignition systems of present engines, but does retain the high energy levels required for ground starting. A detailed review of this design is included in Appendix B. This ignition system is to be flight-tested by Directorate of Flight and All-Weather Test in the near future.

III. CONCLUSIONS

8. Rapid relights are obtainable utilizing continuous ignition on F101A and F101B aircraft under artificially induced ice ingestion.

9. Direct current ignition systems tested are satisfactory for longer duty cycles than presently required by MIL-E-5007A, however, are not adequate for extended continuous duty.

10. Under conditions tested, the spark ignition is capable of more satisfactory rapid relights than the platinum glow plug.

IV. RECOMMENDATIONS

11. The use of continuous spark ignition be thoroughly investigated for specific applications which are prone to flameout under certain flight conditions.

12. The continuous ignition system designed by the Propulsion Laboratory be flight tested in F101B aircraft under ice ingestion conditions.

13. Engine manufacturers develop continuous ignition systems during the development phases of new gas turbine engines as a means of reducing the probability of engine flameout during flight.

14. Determine minimum spark energy and voltage required for rapid relight with the view toward reducing stress and wear on components of a continuously operating ignition system.

COORDINATION:

Robert E. Maloney

Robert E. Maloney, WCLPBRW

Ernest C. Simpson

Ernest C. Simpson, WCLPBR

PREPARED BY:

John J. Rose

JOHN J. ROSE, WCLPBRW

PUBLICATION REVIEW

This report has been reviewed and is approved.

Charles M. Michaels

CHARLES M. MICHAELS,
Chief, Air Breathing Propulsion Division
Propulsion Laboratory

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CONTRACTORS

1 AC Spark Plug Division
General Motors Corporation
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Flint 2, Michigan

1 Allison Division
General Motors Corporation
Attention: Mr. Fred Sietz
Indianapolis 6, Indiana

1 B. G. Spark Plug Corporation
321 Broad Avenue
Ridgefield, New Jersey

1 Boeing Airplane Company
Post Office Box 3707
Seattle 24, Washington

1 Boeing Airplane Company
Wichita, Kansas

1 Bridgeport-Lycoming Division
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1 Continental Aviation & Engineering Company
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1 Douglas Aircraft Company
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Fairchild Engine & Airplane Corporation
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1 General Electric Company
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ATTN: C. J. Watters
Lakeside Avenue
Burlington, Vermont

1 General Electric Company
Jet Engine Division - J93 Project
Evendale Plant
Post Office Box 196
Cincinnati 15, Ohio

1 General Electric Company
Jet Engine Division - J79 Project
Evendale Plant
Post Office Box 196
Cincinnati 15, Ohio

1 General Electric Company
Jet Engine Division - J47 Project
Evendale Plant
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1 General Electric Company
Small Aircraft Engine Department
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1	Scintilla Division Bendix Aviation Corporation Sidney, New York
1	Westinghouse Electric Company Aviation Gas Turbine Division 32 North Main Street Dayton 2, Ohio
1	Wright Aeronautical Division Curtiss-Wright Corporation Woodridge, New Jersey
1	Champion Spark Plug Company ATTN: Mr. L. R. Lentz 900 Upton Avenue Toledo 1, Ohio

APPENDIX "A"

BIBLIOGRAPHY

A. **British Platinum Glow Plug**

1. U.S. Navy, Bureau of Aeronautics, Aer PP-323 correspondence dtd 24 May 1957 to Commander, Wright Air Development Center, ATTN: WCLPR-7, Subject: "Technical Data, forwarding of"

2. Embassy of United States of America, Office of Naval Attache', London, England correspondence NA3:1nA8-30274, dated 16 April 1957 to Chief, Bureau of Aeronautics (ATTN: PP-322), Washington 25, D.C., subject: "Catalytic Ignition in Aircraft Gas Turbine Engines", and inclosures thereto.

B. **Arnold Engineering Development Center**

3. AEDC Technical Report 58-13 (ASTIA Document No. AD 302,751) dated November 1958, subject: "An Investigation of Modifications to the YJ79-GE-3A Turbojet Engine".

C. **Wright Air Development Center Flight Testing**

4. WADC Form 56, Flight Test Request WCLP 58-46 "Rapid Relight Flight Test J57-P-55 Engine, F101B Aircraft Single Igniter 400 Cycle 4 Joule System" 19 December 1958 - Propulsion Laboratory

5. Flight Test Report, WCTET 58-9 (WADC Form 56, WCLP 58-39) "Icing Test of Continuous Ignition System on F101B Aircraft Equipped with J57-P-55 Engines" 5 November 1958 - Directorate of Flight & All-Weather Testing.

6. WADC Form 56, Flight Test Request WCLP 58-42 "Rapid Relight Test of J57-13 Engine, F101A Using Single Igniter, 24 Volt DC 4 Joule System" 20 October 1958 - Propulsion Laboratory

7. WADC Form 56, Flight Test Request WCLP 58-39 "Rapid Relight Test After Flameout J57-P-43 Engine, F101B" 19 September 1958 - Propulsion Laboratory

8. Flight Test Report WCTET 58-6 "Flight Test of Continuous Ignition System on F101 Aircraft" 28 August 1958 - Directorate of Flight & All-Weather Testing

9. WADC Form 56, Flight Test Request WCTE 58-2 "Flight Test of Continuous Ignition During Icing" 30 January 1958 - Directorate of Flight & All-Weather Testing

D. **Ignition System Endurance Testing**

10. Pratt & Whitney Aircraft Interoffice correspondence from Frank Iwanowsky to Charles Goodrich, Subject: "Ignition Endurance Testing" - 14 July 1958

APPENDIX "A" (cont'd)

11. Scintilla Division, Bendix Aviation Corporation, correspondence to WADC Subject: "Continuous Duty Operation for ICN-16 (10-37750-1) Ignition Unit Used on (AF) J57-P-13 Engine" - 31 March 1958

12. Propulsion Laboratory, WADC, Test data "J57 Engine Ignition Endurance Test" 31 March 1958 through 16 April 1958

APPENDIX "B"

A CONTINUOUS IGNITION SYSTEM NOW UNDER CONSIDERATION FOR A.F. USE

A. INTRODUCTION:

1. The ignition systems presently in use on turbojet engines use 24 volt direct current. This is necessary because alternating current is not always available at the engine starting RPM of a windmilling air start. However, now with the rapid relight and higher RPM of the engine, the AC is available and is the most desirable for a continuous operating ignition system. It eliminates the need for electromechanical devices, such as vibrators, used in DC systems which have definite limitations for continuous operation. Also considerable higher voltages will be required for rapid relight due to the high pressures in the combustors. However, the spark energy of the continuous system can be a fraction of present ignition systems, since rapid relight is accomplished under ideal conditions of high pressure and temperature. This can be understood from the fact that glow plugs are producing ignition for rapid relight.

B. DEVELOPMENT AND TEST:

2. Visioning these facts, the Propulsion Laboratory initiated a work program to develop a continuous system which could be readily made available and installed on present aircraft with a minimum of modification to the engine and at the same time keep the present ignition system intact for ground and air windmilling restarts.

3. As a result of this effort, a system shown in Exhibit A and B was devised which can be installed on engines without the installation of additional igniter plugs. Components with continuous capability and which are presently in production were selected for the system. The continuous system parallels the present ignition system to spark a single igniter plug and either system can be selected by switching only the low voltage of each system.

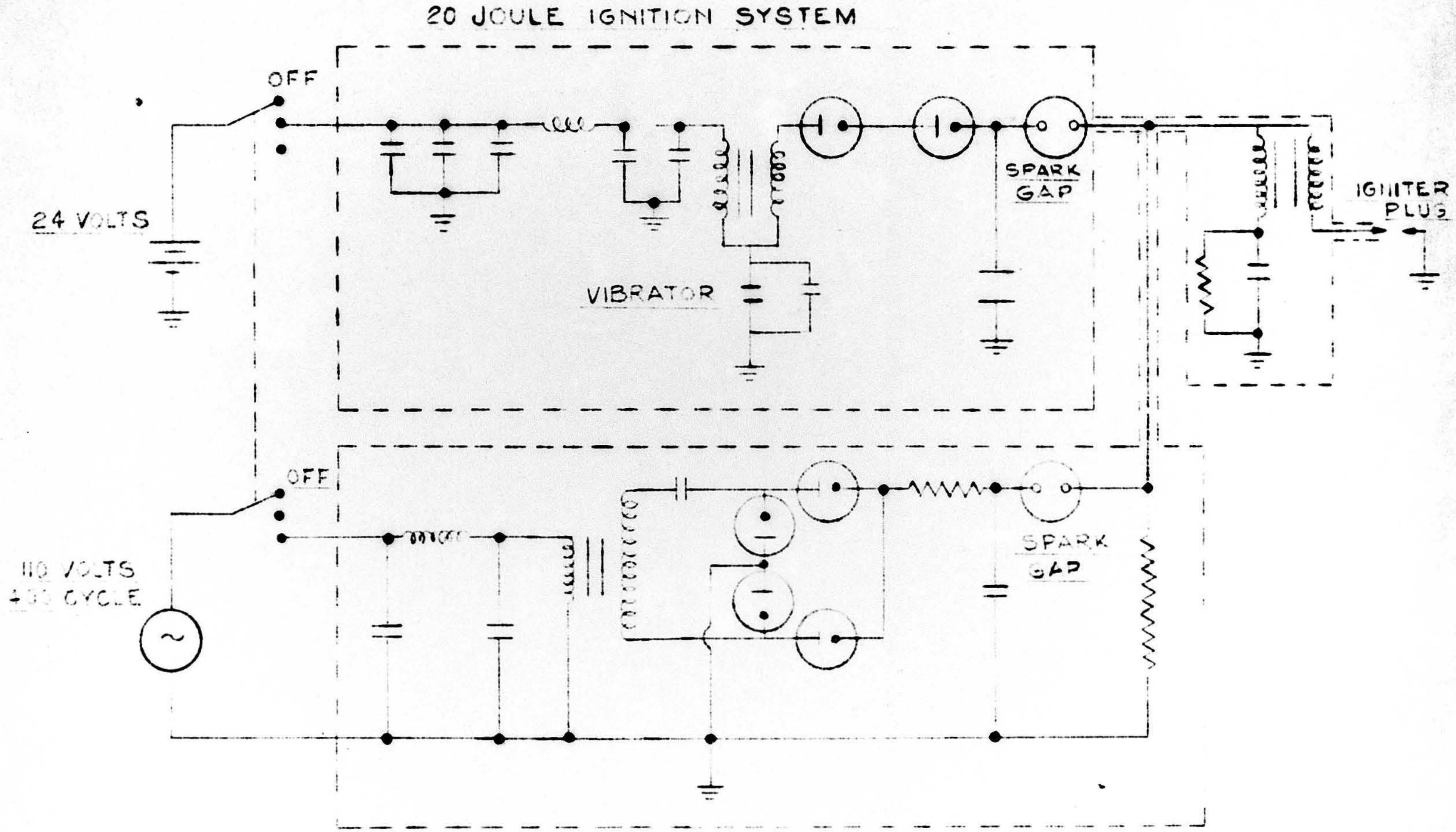

EXHIBIT "A" - 1 JOULE IGNITION SYSTEM

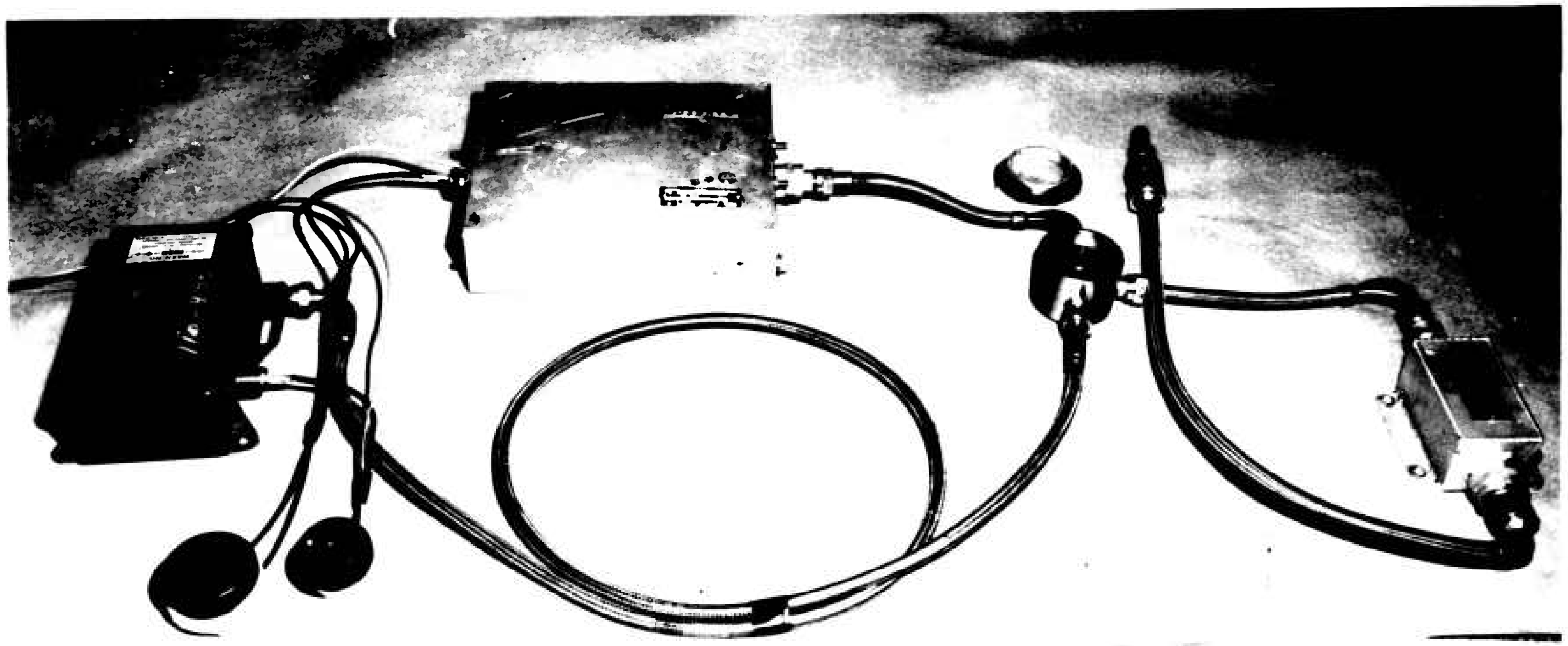

EXHIBIT "B"

LABORATORY PROTOTYPE SYSTEM
TWO INDIVIDUAL IGNITION SYSTEMS
TO OPERATE ON A SINGLE IGNITER PLUG.